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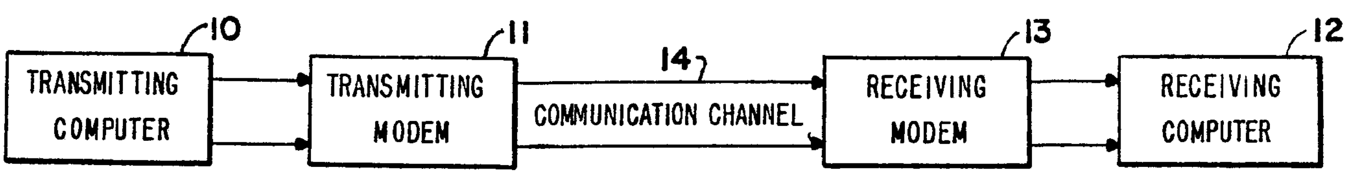

(57) Abstract

A telecommunications system (11) intermittently checks and, if necessary, adjusts the power level of the transmitted data as a function of the transmission characteristics of the transmission line (14) so as to optimize transmission performance.

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METHOD AND APPARATUS FOR EFFECTING EFFICIENT TRANSMISSION OF DATA

This invention relates generally to a telecommunications system adapted to transmit digital data, and more particularly to a system which intermittently checks and, if necessary, adjusts the power level of the transmitted data as a function of transmission characteristics of the transmission line so as to optimize transmission performance.

BACKGROUND OF THE INVENTION

While microcomputers were once only used as dedicated and completely isolated devices, they are now used for a wide range of applications, many of which require microcomputers to communicate with each other or with larger centrally located computers. This communication frequently is accomplished over voice grade communication channels. Modems are used to convert digital data from the computer to analog data for transmission over these voice grade communication channels and subsequent redigitization upon receipt. As signal processing techniques have advanced, modem technology has also advanced providing the capability of transmitting at higher speeds over voice grade channels. Problems maintaining the data integrity across the communications channel have developed with such high speed communication because the higher speed data transmission methods are more vulnerable to noise interference within the communication channel. To facilitate higher speed communicatons, communications protocols have been developed to detect and correct data transmission errors and ensure data integrity across the channel.

A communication protocol is basically a set of rules that defines how communicating devices interact. For one device to transfer data successfully to another, both devices must observe the same protocol. Typcially, a

protocol specifies when to send a message, how to format the information in the message, and at the other end, how to acknowledge the receipt of the message.

Simple physical connect protocols are concerned only with hardware configurations. Establishing the basic physical connection between two modems requires that a particular series of steps be followed. The originating modem initiates its sending sequence, and the telephone number representing the electronic address of the receiving modem is formatted as a series of pulses or tones and sent to the telephone network. The receiving modem senses the incoming call as a relatively high voltage (sufficient to cause a phone to ring) and interprets this as a request to establish a connection. The modems then proceed to establish the physical connection via a series of signal exchanges that result in a particular connection protocol. Such a connection is possible because both modems use the same physical connect protocol. These basic physical connect protocols are fairly standard. CCITT specifications V.22, V.22bis, V.29, V.32 and V.32bis are common as well as Bell 212A. These physical level protocols do not ensure error free communication.

Connecting two computers is only a small part of the communications work necessary for accurate data transfer. As described in greater detail below, the transmission medium through which the data is sent is often noisy, and errors can crop up in the transmitted data. These errors must be detected and corrected. The resources available to store incoming data also must be passed and matched so that the recipient is not flooded with data. These concerns, therefore, go beyond the physical level protocols. A higher level protocol is required to ensure error free communications.

One protocol which enables error free communications between modems is the Microcom Networking Protocol (MNP) which has been developed by Microcom, Inc. of Norwood, Massachusetts. MNP provides a sophisticated communications

system which includes provisions for both reliable terminal-type interactive communications and reliable file transfer. MNP provides sophisticated error checking and correction as well as data compression. MNP is widely used to provide error free communications.

The MNP protocol, which has been developed principally for use with microcomputers, includes three layers, and the use of only three layers enable MNP to provide the necessary services with the desired space and performance characteristics for a microcomputer environment. The three layers or modules are combined to perform a series of complex functions in a manner in which changes in one module may not drastically affect another module, as long as certain parts of the module's interface remain the same.

In MNP, each layer is relatively isolated and provides a specific service. If a change is forced in one layer (for example, if MNP is modified for use on a new computer), the change is confined to that layer while the layer's standard interface to the other layers remains unchanged. In addition to ensuring machine portability, MNP's structure allows services provided by one layer to support those in the layer above. The accumulation of services is then passed upward, from layer to layer to the applications program. MNP defines three unique protocol layers in addition to the physical connection; the link, the session, and the file protocol layers. The protocol layers are triggered sequentially from the bottom (physical) to the top (file transfer).

The link layer is responsible for providing reliable, controlled data transmission over a medium that is inherently noisy and likely to cause errors. Once a physical connection is established between two modems, the link protocol acts as a negotiator causing both devices to agree on the nature of the link. For example, the link protocol establishes whether the connection will be half- or full-duplex, how many data messages can be sent before confirmation is required, the size of a single data packet,

etc. As will be more evident hereinafter, the link protocol utilized in the preferred embodiment is modified to include the necessary information to carry out the principles of the present invention. After establishing values for the above requirements, the link protocol initiates data transfer, paces the flow of data and, if necessary, re-transmits data messages that contain errors due to telephone line noise. The link protocol allows blocks or packets of data (as opposed to individual bytes) to be sent synchronously or asynchronously to the receiving computer. Data transfer is faster when packets are transmitted synchronously because start and stop characters are not needed, and as a result, the ratio of data to control characters regulating the transfer is higher. Control is possible because of a mainframe-like (framing) technique in which a block of data is carried from both ends with specific codes.

In order for any communications protocol to facilitate communications among a wide variety of computers, the protocol must be able to operate in a number of modes. These modes include a matched-protocol mode for use by two communicating devices supporting the same protocol. Such a matched-protocol mode may provide optimized data transmission including a number of known optimizing features such as detecting and correcting errors, data compression, and optimizing transmission speed. The latter is achieved in the link layer of the MNP protocol by sensing the error rate. Should the error rate be too high at the receiving end, the receiving end provides an indication that the signal to noise ratio is too low for the attempted modulation rate (i.e., baud rate) so the transmitting modem downshifts, i.e., transmits at a slower modulation rate to improve signal quality. Conversely, should the transmission of data be error free the receiving modem can instruct the transmitting modem to upshift to a higher modulation or baud rate so that data can be transmitted at a higher and more efficient modulation rate

so as to increase data throughput without sacrificing quality.

Certain communciation channels, such as cellular networks, are particularly noisy. The noise levels in the transmission channels are directly related to the signal to noise ratio, which in turn is directly related to the available throughput (the maximum rate at which information can pass through the particular transmission channel). Even worse, as transmission of a signal passes from one cell to another cell in a cellular communications network the quality of the line can abruptly change. This wide range of line quality can result in demodulation errors. Worse, the line temporarily can disconnect resulting in disruption in the line. While such disruption can be acceptable for voice communications it can be disastrous for data transmission since the carrier signal, and thus a great deal of transmitted data, can be lost. In the latter situation the two modems must be "retrained" so that the two modems are suitably resynchronized with one another and data can be transmitted between the two.

This problem is exacerbated because companding techniques often are utilized in cellular communications because the dynamic range of the transmission medium is particularly small (the power level range between a floor where noise will mask a transmitted signal, and a ceiling where transmitted signals saturate and thus distort). Accordingly, signals are first dynamically compressed prior to being transmitted through the transmission channel, and subsequently dynamically expanded when received from the transmission medium so as to preserved the dynamic range of the original signal. When compressing a signal the gain impressed on the transmitted signal is automatically controlled as a function of the power level of the original signal so that the power level is actually boosted for low power levels and attenuated for high power levels by a predetermined compression factor (as a function of the dynamic range of the transmission medium). Thus, a greater

range of power levels of the transmitted signal, once compressed, can be transmitted within the narrower dynamic range of the transmission channel. The signal is expanded in a complementary manner at the receiving modem so that the signal is restored to its original dynamic range without distortion or loss. This compression and complementary expansion factor (i.e., companding factor) is typically determined by the location of the floor and ceiling of the dynamic range of the transmission medium, and for cellular communciations is specified in cellular network standards. It is customary that the power level of the original signal is preset at a predetermined level above the noise floor of the transmission channel when transmitting the signal so as to optimize the transmission performance. This easily can be done for a communication channel where the dynamic range and noise floor are fairly fixed. However, in cellular communications as the transmission of a signal is passed from one cell to another, the transmission characteristics of the channel may change (i.e., the attenuation drop can vary), which in turn can result in the power level of the received signal dropping below the noise floor. This can result in the noise masking the signal causing data to be lost or received in error. Thus, the optimum power level for transmission through one cellular transmission channel may not be optimum for another.

OBJECTS AND SUMMARY OF THE INVENTION

It is therefore a principal object of the present invention to provide an improved system for and method of transmitting data in which the power level of the transmitted signal is adaptive to transmission characteristics of the transmission line so as to optimize transmission performance.

Another object of the present invention is to provide a system for and method of data transmission in which the optimum power level of the transmitted signal is

intermittently determined in real time as a function of the transmission characteristics of the transmission channel.

Still another object of the present invention is to provide a data communications system and method in which the optimum power level for transmitting signals between two modems is updated when upshifting or downshifting the modulation rate, or retraining to resynchronize the modems.

Yet another object of the present invention is to provide an improved data communications system and method, particularly useful for compressed signals transmitted over a communciations channel, in which the power level of the transmitted signal is optimized as a function of the intermittently measured quality of the transmission channel through which the signal is transmitted.

These and other objects of the present invention are provided by an improved data communications system and method which intermittently updates, and changes if necessary, the power level of a transmitted signal as a function of the location of the noise floor of the transmission channel and line attenuation so as to approximate the power level for optimum transmission performance through the channel and accommodate changes in transmission characteristics in the channel.

Other objects of the invention will in part be evident and will in part appear hereinafter. The invention accordingly comprises the processes involving the several steps and the relation and order of one or more of such steps with respect to each of the others, and the apparatus possessing the construction, combination of elements, and arrangement of parts which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the present invention, reference should be had to the following detailed description taken in connection with the

accompanying drawings wherein:

Fig. 1 is a generalized schematic view of a data telecommunications system of the type including two modems incorporating the present invention;

Fig. 2 is a schematic view of a modem of the present invention;

Fig. 3 is a graphical illustration showing an example of a typical relationship of eye quality monitor data and the signal to noise ratio of the transmission channel for quadrature amplitude modulated (QAM) signals;

Fig. 4 is a graph illustrating the limits of power level of a transmitted signal through a transmission channel of a typical cellular network;

Fig. 5 is a flow diagram of the steps utilized by the modem of the present invention in optimizing the transmitted power level as a function of transmission characteristics of the transmission line;

Fig. 6 is a flow diagram of a subset of steps utilized by the modem of the present invention relating to the check line quality step 104 of the flow diagram of Fig. 5; and

Fig. 7 is a flow diagram of a futher subset of steps utilized by the modem of the present invention relating to the update transmit level step 206 and 215 of the flow diagram of Fig. 6.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A basic data telecommunications system incorporating the present invention is shown in Fig. 1 and includes a transmitting unit of data terminal equipment (DTE) 10, such as, but not limited to, a dumb terminal or a microcomputer, and a receiving unit of DTE 12. An initiating modulator/ demodulator (modem) 11 is connected between unit 10 and a communication channel (such as, but not limited to a cellular network transmission channel) and a receiving modem 13 is connected between unit 12 and communication channel 14. It should be appreciated that while designating one computer and modem as initiating and the

other computer and modem as receiving, in reality in most instances both are capable of transmitting and receiving data between one another through the transmission channel. Thus, the designations are for convenience, with the designations "initiating" and "transmitting" used to mean that a computer and modem are transmitting data, and the designation "receiving" used to indicate that a computer and modem are receiving data from the transmitting modem.

A modem of the communication system of the present invention is shown in greater detail in Fig. 2. The communications system of the present invention will normally include at least two modems of the type described below. For purposes of the following discussion, the modem of the system will be described with reference to both the transmitting and receiving modes, and thus will apply to each of the modems 11 and 13 of Fig. 1. The modem shown in Fig. 2 includes a DTE-interface 15 which receives data coming from corresponding DTE unit. Data characters supplied to the DTE-interface 15 pass through a communications port 16 of the microprocessor 18 to which characters are fed either in a serial or parallel fashion. The microprocessor 18 has connected to it status indicators 20, a program and data memory 22 (the latter including a buffer memory 23) and parameter setting switches 24. Timing synthesizing circuitry 26 is also connected to the microprocessor 18. Data processed by the microprocessor 18 is sent through a modem port 28 to modulation circuits 30 which in turn will pass data through a filter 32 before applying the signals to the interface 34. In the case of cellular network transmission, the signal is applied to a transceiver 36, equipped with a compander for compressing the transmitted signal before transmitting the signal over the communication channel 14 to the remote modem. The modulation circuits 30 preferably are adapted to modulate the signal to be transmitted in accordance with a quadrature amplitude modulation (QAM) technique at any one of serveral modulation or baud rates, which can change with

an upshifting, downshifting or retraining operation, which will be described in greater detail hereinafter in connection with a description of the preferred embodiment of the present invention.

The modem of Fig. 2 also includes demodulation and data recovery circuits 38 used for receiving and demodulating data from another remotely situated modem. When the modem of Fig. 2 acts as a receiving modem, data passes through transceiver 36 (where the transmitted compressed signal is expanded to its original dynamic range), interface 34 and filter 32 to the circuits 38. The demodulation rate is set based on the modulation rate. Accordingly, provision is made as a part of the link protocol for determining the modulated rate at which data is to be transmitted and setting the demodulation and data recovery circuits 38 accordingly.

According to the present invention, the modems of the system function to intermittently update, and change if necessary, the power level of a transmitted signal as a function of the line quality (i.e., in the preferred embodiment the location of the noise floor of the transmission channel) and an indication of the received level of the transmitted signal (i.e., in the preferred embodiment the received level is an indication of line attenuation) so as to approximate the power level for optimum transmission performance through the channel and accommodate changes in transmission characteristics of the channel.

More specifically, as indicated in Fig. 3, as is well known there is a relationship between what is referred to as the eye quality monitor (EQM) value and the signal to noise (S/N) ratio (and thus the position of the noise floor) of the transmission channel 14. Thus, the EQM value is one measure (when transmitting a QAM signal) of line quality. The EQM value is determined as the filtered squared magnitude of the error vector, the latter being defined as the angle and magnitude difference between an

actual received signal point of a QAM signal, and its ideal location in the baseband signal plane. As is well known in the art the EQM value may be obtained by processing the error vector data to obtain a positive hexdecimal value whose magnitude is an indicator of the quality of the received signal or probability of error of received signal points. See Laiz, Carlos; "Quality of Received Data for Signal Processor-based Modems"; Rockwell International; Document No. 29220N71; Application Note Order No. 671; February, 1985; pages 1-20. In accordance with the the present invention, an EQM value is preselected as a function of the minimum permissible S/N so that the power level of the transmitted signal is as close to the noise floor as permitted without significant loss of information. The ideal power level is initially presumed to be -10dB, although this will vary in accordance with the principles of the present invention based upon the attenuation over the transmission channel. Accordingly, the modem of the present invention includes means 40, connected with the demodulation circuits 38, for providing a signal (preferrably as a function of the EQM value determined from a signal received over the channel 14) to the microprocessor 18, representative of the line quality, i.e., preferrably the current S/N as sensed, in real time, from the signals received from the remote modem, and thus the location of the noise floor of the channel 14.

While the EQM value provides a good indication of how far the received signal is from the noise floor in the communication channel, for a given level of transmitted signal, the level of the received signal (i.e., the line attenuation) can vary and thus, there is no indication of what the power level of signal should be when transmitting the signal over the channel 14 so as to provide a desired level of received signal. More specifically, as illustrated in Fig. 4, the power level of the transmitted signal drops as a function of the attenuation along the transmission channel. Ideally, the EQM value of the

received signal should be representative of a S/N as small as possible without the noise masking the signal so as to utilize as much of the dynamic range of the transmission channel as possible. Thus, if a particular line attenuation is assumed and the power level is set based upon a particular EQM value which place the received signal as close as possible to the noise floor at the receiving end, a line providing greater attenuation may result in the signal falling below the noise floor, while a line providing less attenuation may result in signal saturation. Accordingly, means 42, connected with the means 40, are provided for intermittently measuring, in real time, the attenuation along the channel 14 so that the power level can be set so that the EQM value at the received end of the channel 14 is at the appropriate preselected value. Means 42 therefore provides a signal representative of the line attenuation of the channel 14, referred to in the preferred embodiment as the "AGC value". Preferably, the line attenuation is intermittently checked by transmitting a signal as a known power level and measuring the power level of the received signal.

According to the present invention, the preferred modem of Fig. 2 intermittently checks and, if necessary, changes the power level of the transmitted signal from one modem to another by determing the EQM value provided by the EQM means 40 and the AGC value provided by means 42. Each time the EQM and AGC values are determined at the remote modem, the values are transmitted back as a part of the link protocol. Having the two measurements provides an accurate measure of line transmission characteristics so that the transmit power level can be set as low as possible without the transmitted signal falling below the noise floor.

The optimization is preferably performed intermittently and in real time so that changes in the transmitting environment will result in changes in transmitted power level thereby maintaining optimum

throughput.

In accordance with the present invention the optimization of the transmitted power level is performed during upshifts or downshifts of the modulation rate of the transmitted signal, or during retraining when two modems are reconnected. Referring to Figs. 5-7, the flow diagrams show the operation of the modem in carrying out the principles of the present invention, and preferably use the MNP protocol to transmit local data and receive remote data. The preferred program code for carrying out the steps of the optimization of the power level is carried out in the microprocessor 18, and is described and shown in Appendix A.

Specifically referring to Fig. 5, the steps described, with the exception of steps 104, 107 and 112, are well known as a part of the error control function of the MNP protocol and are described as a part of the preferred embodiment within which the principles of the present invention are utilized. As shown in Fig. 5, the error correction function of microprocessor 18 polls the hardware to obtain the values of EQM and AGC from means 40 and 42 necessary to carry out error correction and adjust the power level in accordance with the present invention. In this regard the system generates the link management idle packet in order to establish a connection between the two modems. Specifically, at step 101 of Fig. 5, the protocol link is established, i.e., the originating modem sends a link request to the remote modem. The receiving modem receives and evaluates the link request to determine what it can support and sends back similar information. In this regard the information exchanged between the two modems include the current values of EQM and AGC, which as will be more evident hereinafter determines the initial power level at which the signal is to be transmitted as indicated at step 102. Initially, these values are set for a power level of -10dB. After an initial settling time the values of EQM and AGC are read. In the preferred embodiment in

accordance with the MNP protocol, if not already set at the highest modulation rate, it is preferred that the latter initially is chosen as the initial transmission rate at step 103.

Step 104 is the step at which the line quality is checked, and is described in the form of a series of substeps shown in flow diagram form in Fig. 6. Referring to Fig. 6, step 104 includes steps 201-222, all of which are intended to be a part of the MNP protocol, with steps 202, 206 and 215 being inserted within the protocol according to the principles of the present invention. More particularly, the subset of steps are designed to check the line quality. If the link management idle frame is received at step 201, the next transmit level is calculated at step 202 and in particular in accordance with the subset of steps shown in Fig. 7.

Referring to Fig. 7, calculations are made to determine the next transmit level so that the values can be updated at steps 206 and 215, described hereinafter. Specifically, at step 301 the values of EQM and AGC are validated. If the transmitting modem is unable to determine values provided by the remote modem, the transmitting modem transmits an indication of such (preferrably an FFHex byte) within the LMI frame as a part of step 108 or 113 of Fig. 5, described hereinafter. The subset of steps of Fig. 7 then returns to step 203 of Fig. 6. If however, updated values can be determined, they are adjusted at steps 302 and 303 by the microprocessor. If, for example, the initial transmit level is set at -22dB and the level is received at -30dB, the line attenuation is -8dB (the difference between the transmit and received levels). The preferred transmit power level at which the compander will provide unity gain is determiend at step 302 based on the AGC value received form the other modem and the current transmit power level. In addition, the minimum transmit power level at which the noise floor will not interfere with the data transmission is determined at step

303 based on the AGC and EQM value received from the other modem and current transmit power level. Given the two measurements, the microprocessor utilizes an empirically determined table, shown in Appendix A to adjust the signal strength (power level) of the transmitted signal at step 302 based on one of the two measurements made at steps 302 and 303. The values in the table of Appendix A have been empirically determined. As to which measurement is used to set the next power level will depend of the EQM value. If the EQM value indicates a high noise level at step 304, the processor will utilize the data acquired at step 303 to set the power transmit level from the table of Appendix A, as indicated at step 306. If, however, the EQM value indicates an acceptable noise level at step 304, the microprocessor proceeds to step 305 and calculates the new power level based on the AGC number from the table of Appendix A. In either event the microprocessor returns to step 203 shown in Fig. 6. Referring again to Fig. 6, once the next transmit level has been determined, or if at step 201 a link management idle frame has not been received, the program proceeds to step 203 to see if the "fall back" command has been received. If the fall back command is received, indicating that the remote modem has decided to downshift so that the current modem will receive data at a slower rate, the microprocessor will provide an acknowledgement at step 204. The modem will first update the power level at which the modem will transmit at step 206 before proceeding to step 207 where the modulation rate is actually changed to the next lower rate. At step 208 the system checks to insure the downshift is successful, and if so the modem proceeds to step 105 of Fig. 5. If, however, the modem is not successful at step 208, the modem proceeds to step 205 to again try a fall back to a slower modulation rate. If successful at step 205, the system returns to step 206. However, if not, the modem proceeds to disconnect.

If at step 203 of Fig. 6 the fall back command is not

received, the microprocessor proceeds to step 209, the quality of the line is measured at step 209 by sensing the EQM value provided in the EQM means 40 so as to determine whether the modem should downshift. If yes, the microprocessor proceeds to step 210 to determine whether the modem can operate at a slower speed. If yes, the modem sends a fall back command at step 211 and proceeds through steps 206, 207 and 208, (and step 205 if necessary) as previously described. If, however, the modem cannot downshift as determined at step 210 (the modem is operating at its slowest speed), or if at step 209 the line quality is not judged to be bad, the microprocessor proceeds to step 212.

At step 212, the modem checks to see if a fall forward command has been received from the remote modem, indicating that the remote modem wishes to operate at a faster modulation rate. At step 213 an inquiry is made as to whether the modem can operate at a faster speed, and if not the microprocessor proceeds to step 218 to send a fall forward negative acknowledgement indicating to the remote modem that the modem cannot operate at the faster speed. The program then returns to step 105 of the flow chart of Fig. 5. If, however, an upshift can occur the program proceeds to step 214, whereupon a fall forward acknowledgement signal is sent to the remote modem at 214, the transmit level data is updated (in an identical way as described above with respect to step 206, and substeps 301-306). The modulation rate is upshifted at step 216, and the system checks to be sure the upshift was successful at step 217. If not the system repeats the steps 206, 207, 208 (and if necessary 205) by again updating the transmit level and changing the modulation rate. If once again unsuccessful the system disconnects. If successful at step 208 or step 217, the system returns to step 105 of Fig. 5.

If a fall forward command is not received from the remote modem, the system proceeds to step 219. The line quality is again checked by reading the EQM value. If the

line quality is still good, a determination is made whether to upshift at step 220. If yes, the system sends a fall forward command to the remote modem and waits for the fall forward acknowledgement signal to return at step 222. If the latter signal is received the system proceeds through steps 215, 216 and 217, and if unsucessful at step 217, proceeds through steps 206, 207 and 208 (and step 205, if neccessary). If unsuccessful at step 205, the system disconnects. If successful at step 217, or subsequently successful at step 208 the system returns to step 105 of Fig. 5. Similarly, if the line quality is judged at step 219 to be bad, or the modem cannot upshift at step 220, or the fall forward acknowledgement signal is not received at step 222, the system similarly returns to step 105.

Referring again to Fig. 5, at step 105, the microprocessor determines whether a data packet is to be sent. An idle timer is set at the end of the transmission of each data packet and allowed to run until the next packet is sent. Thus, the idle timer can be used to determined whether the two connected modems are idle (no data is being sent). The modems are considered idle if no data is sent within a predetermined period of time, e.g., 1.0 seconds. Thus, if no data packet is to be sent at step 105 the microprocessor proceeds to step 106 to determine whether the idle timer has expired. If no, the microprocessor proceeds back to step 104. If the idle timer has expired, the microprocessor proceeds to step 107 where the current EQM and AGC values are read from the EQM means 40 and AGC means 42. With the modems being determined in the idle state, the link management idle frame or packet is sent as indicated at step 108. The idle timer is then reset at step 109 and the program returns to step 104.

If at step 105 data is to be sent, the program proceeds to step 110, wherein the receiving modem checks to be sure no that no errors in the packet received from the transmitting modem have occurred. If no, the next data

packet can be sent as indicated at step 111, and the program proceeds to reset the idle time at step 109 before starting over at step 104. If an error is discovered at step 110 the signal strength and quality are both read at step 112 (in the same manner as step 107), and an link management frame is sent at step 113 (in the same manner as step 108), as described in greater detail in Fig. 7. From step 113, the program proceeds to step 114 whereupon the NAK'D (negative acknowledgement) data packet is retransmitted, the idle timer 109 is reset at step 109 and the program restarts at step 104.

The modem and its operation thus described provides an improved system for and method of transmitting data in which the power level of the transmitted signal is adaptive to line conditions so as to optimize transmission performance. The optimum power level of the transmitted signal is intermittently determined in real time as a function of the line conditions. The transmitted power level is updated when checking whether to upshift or downshift the modulation rate, or retraining to reconnect modems. The system and method are particularly useful for compressed signals transmitted over a transmission channel in which the power level of the transmitted signal is intermittently optimized as a function of the noise level within and the attenuation across the communication channel.

Since certain changes may be made in the above process and apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted in an illustrative and not in a limiting sense.

CLAIMS

What is claimed is:

1. A system for optimizing conditions for transmitting and receiving data signals over a transmission medium having transmission characteristics which may change over time, said system comprising:

means for intermittently sensing the transmission characteristics of said transmission medium; and

means for adjusting the power level of data signals transmitted by said system over said transmission medium as a function of said sensed transmission characteristics so as to optimize transmission performance.

2. A system according to claim 1, wherein said means for intermittently sensing the transmission characteristics of said transmission medium includes means for generating a signal as a function of the line quality , and means for generating a signal as a function of the signal attenuation along said medium.

3. A system according to claim 2, wherein said means for generating a signal as a function of the line quality generates said signal as a function of signal to noise ratio of a received signal transmitted through said medium.

4. A system according to claim 3, wherein said signal transmitted over said transmission medium is quadrature amplitude modulated, and said means for generating a signal as a function of the signal to noise ratio includes means for determining the eye quality monitor value of said received signal.

5. A system according to claim 2, wherein said means for generating a signal as a function of the attenuation along said transmission medium includes means for generating a signal at an initial power level along said

medium so that the attenuation can be measured along said medium.

6. A system according to claim 2, wherein said means for adjusting the power level of data signals transmitted by said system over said transmission medium as a function of said sensed transmission characteristics includes means for storing a table of values empirically determined as the appropriate values of transmitted power levels as a function of the line quality and line attentuation.

7. A system according to claim 2, wherein said means for generating a signal as a function of the attenuation along said transmission medium includes means for generating a signal at an initial power level along said medium so that the attenuation and line quality can be measured along said medium.

8. A method of optimizing conditions for transmitting and receiving data signals over a transmission medium having transmission characteristics which may change over time, said method comprising the steps of:

intermittently sensing the transmission characteristics of said transmission medium; and

adjusting the power level of data signals transmitted over said transmission medium as a function of said sensed transmission characteristics so as to optimize transmission performance.

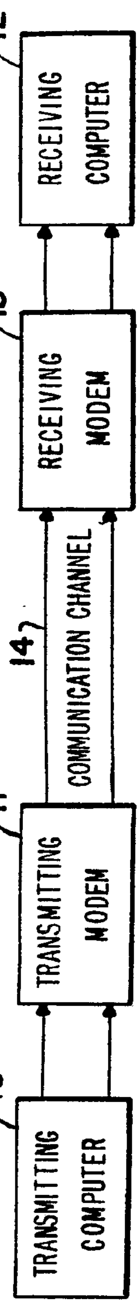
TRANSMITTING COMPUTER
10
TRANSMITTING MODEM
11
COMMUNICATION CHANNEL
14
RECEIVING MODEM
13
RECEIVING COMPUTER
12

FIG. 1

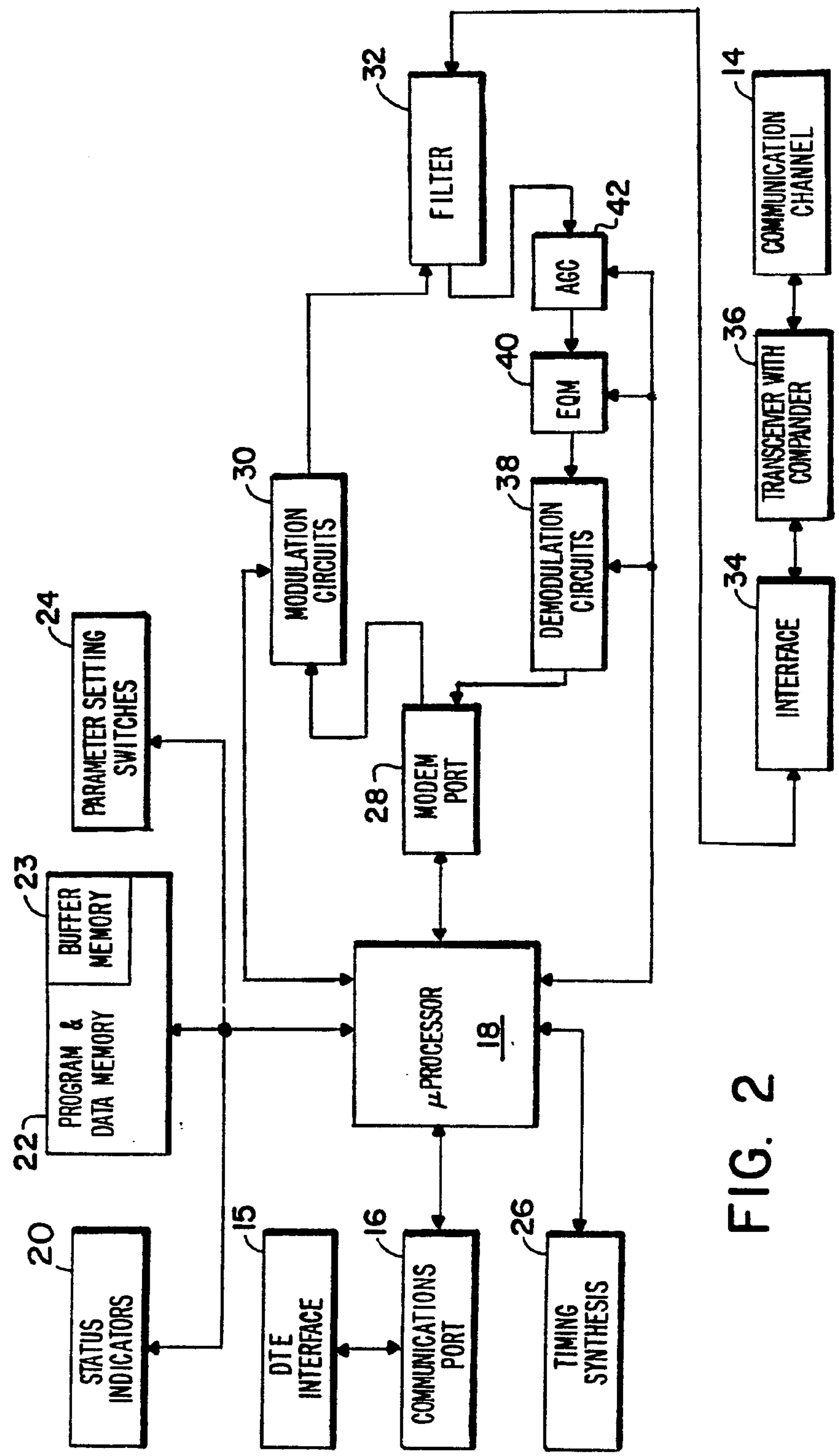
STATUS INDICATORS
20
DTE INTERFACE
15
COMMUNICATIONS PORT
16
TIMING SYNTHESIS
26
PROGRAM & DATA MEMORY
22
BUFFER MEMORY
23
PARAMETER SETTING SWITCHES
24
μPROCESSOR
18
MODEM PORT
28
MODULATION CIRCUITS
30
DEMODULATION CIRCUITS
38
EQM
40
AGC
42
FILTER
32
INTERFACE
34
TRANSCEIVER WITH COMPANDER
36
COMMUNICATION CHANNEL
14

FIG. 2

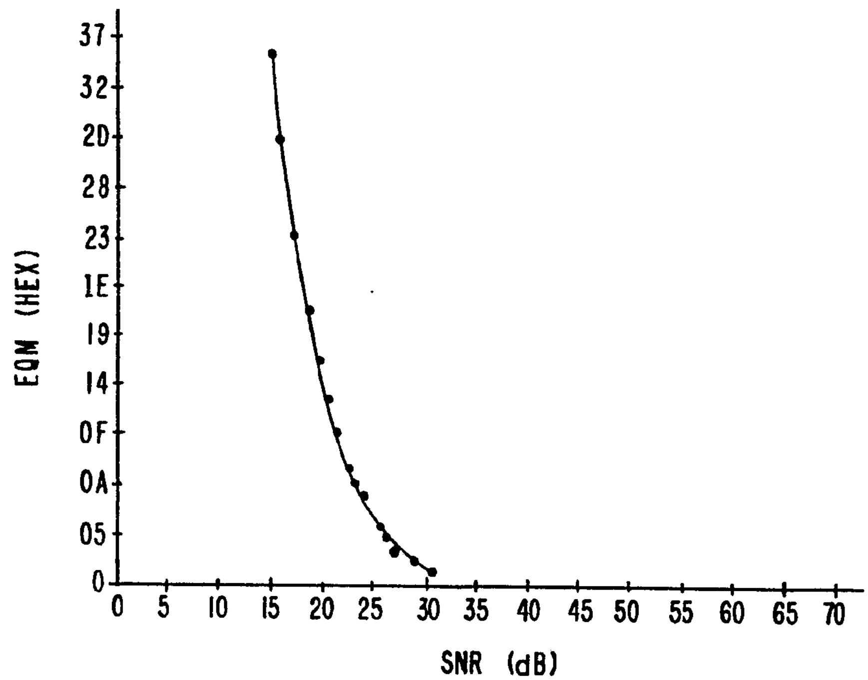
EQM (HEX)
37
32
2D
28
23
1E
19
14
0F
0A
05
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
SNR (dB)

FIG. 3

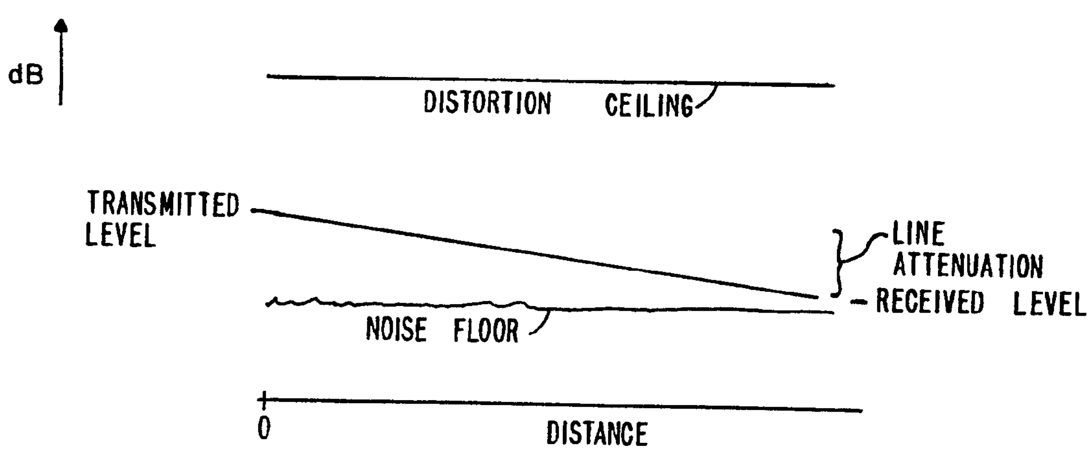
dB
DISTORTION CEILING
TRANSMITTED LEVEL
LINE ATTENUATION
RECEIVED LEVEL
NOISE FLOOR
0
DISTANCE

FIG. 4

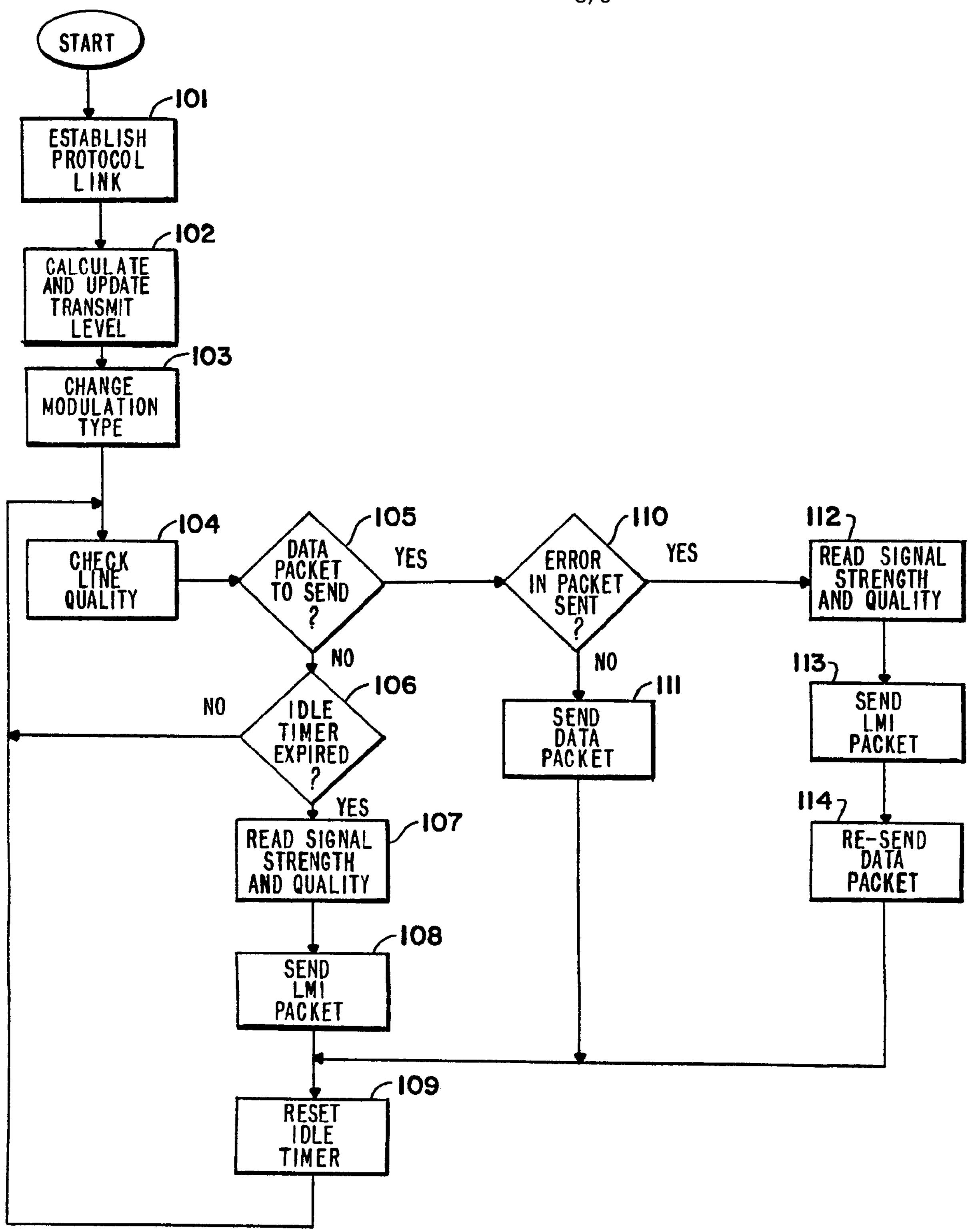
START
101
ESTABLISH PROTOCOL LINK
102
CALCULATE AND UPDATE TRANSMIT LEVEL
103
CHANGE MODULATION TYPE
104
CHECK LINE QUALITY
105
DATA PACKET TO SEND ?
YES
NO
106
IDLE TIMER EXPIRED ?
NO
YES
107
READ SIGNAL STRENGTH AND QUALITY
108
SEND LMI PACKET
109
RESET IDLE TIMER
110
ERROR IN PACKET SENT ?
YES
NO
111
SEND DATA PACKET
112
READ SIGNAL STRENGTH AND QUALITY
113
SEND LMI PACKET
114
RE-SEND DATA PACKET

FIG. 5

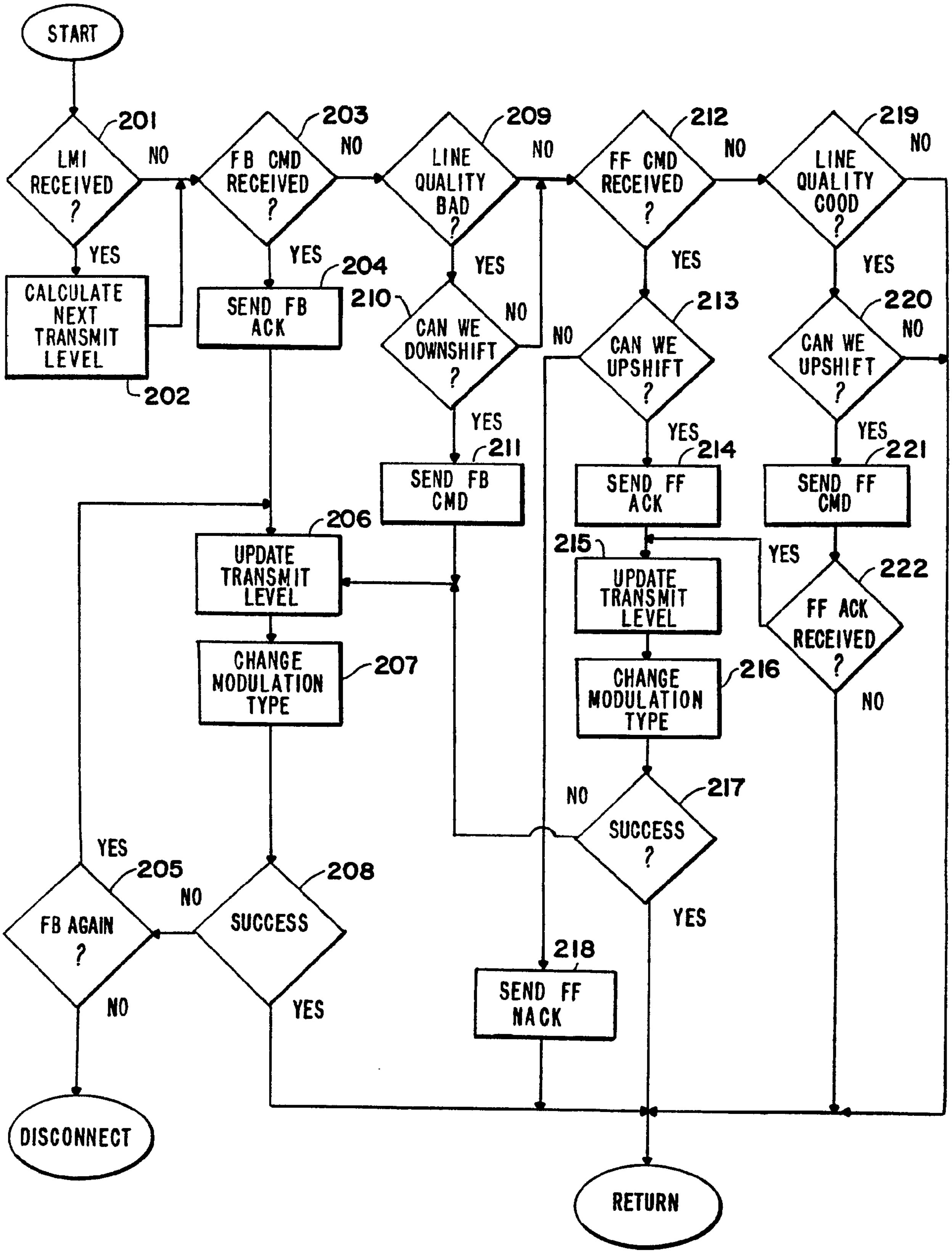
START
LMI RECEIVED ?
201
NO
YES
CALCULATE NEXT TRANSMIT LEVEL
202
FB CMD RECEIVED ?
203
NO
YES
SEND FB ACK
204
LINE QUALITY BAD ?
209
NO
YES
CAN WE DOWNSHIFT ?
210
NO
YES
SEND FB CMD
211
FF CMD RECEIVED ?
212
NO
YES
CAN WE UPSHIFT ?
213
NO
YES
SEND FF ACK
214
LINE QUALITY GOOD ?
219
NO
YES
CAN WE UPSHIFT ?
220
NO
YES
SEND FF CMD
221
FF ACK RECEIVED ?
222
YES
NO
UPDATE TRANSMIT LEVEL
206
CHANGE MODULATION TYPE
207
UPDATE TRANSMIT LEVEL
215
CHANGE MODULATION TYPE
216
SUCCESS ?
217
NO
YES
FB AGAIN ?
205
YES
NO
SUCCESS
208
NO
YES
SEND FF NACK
218
DISCONNECT
RETURN

FIG. 6

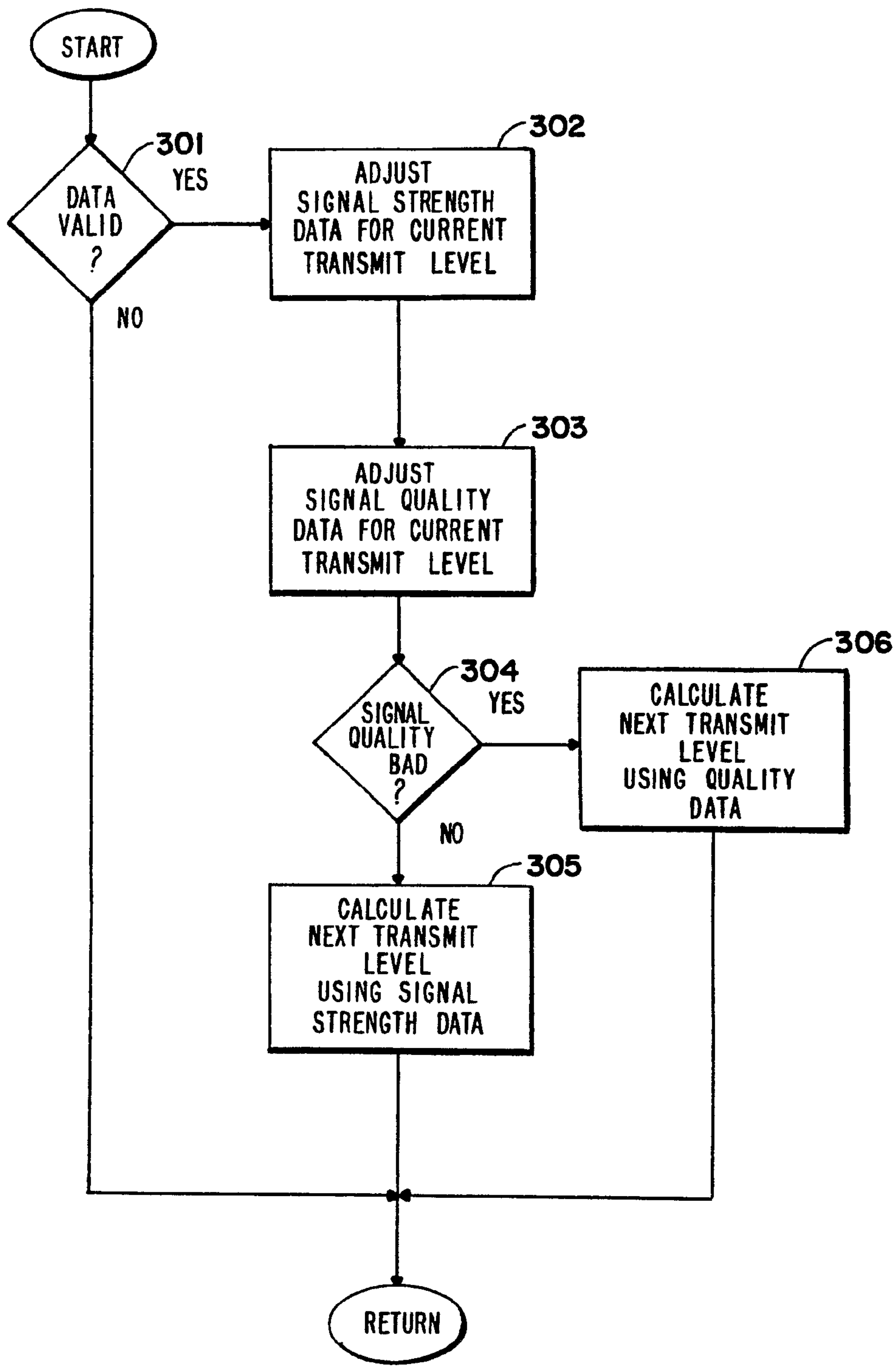
START
DATA VALID ?
301
YES
NO
ADJUST SIGNAL STRENGTH DATA FOR CURRENT TRANSMIT LEVEL
302
ADJUST SIGNAL QUALITY DATA FOR CURRENT TRANSMIT LEVEL
303
SIGNAL QUALITY BAD ?
304
YES
NO
CALCULATE NEXT TRANSMIT LEVEL USING QUALITY DATA
306
CALCULATE NEXT TRANSMIT LEVEL USING SIGNAL STRENGTH DATA
305
RETURN

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/05347

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :HO4B 1/10, H04L 27/08
US CL :375/58
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/98.99; 455/10,52.1,69,70,72; 332/107

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y,E	US, A, 5,128,965 (HENRIKSSON) 07 July 1992, Fig. 1.	1,8
Y	US, A, 4,910,792 (TAKAHATA ET AL.) 20 March 1990, Fig. 5 or Fig. 6.	1,8
Y	US, A, 4,309,771 (WILKENS) 05 January 1982, Fig. 2 and Fig. 4.	1,4,8
A	US, A, 4,004,224 (ARENS ET AL.) 18 January 1977.	1,8
A	LAIZ, CARLOS, "Quality of Received Data for Signal Processor-Based Modems"; Rockwell International; document No. 2922ON71; Application Note Order No. 671; 2/85; pgs. 1-20.	3, 4

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 AUGUST 1992	29 OCT 1992

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